

UMass Participation in Air-Sea Flux Estimation in High Wind Boundary Layers

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<http://www.ecs.umass.edu/ece/labs/mirsl/hurricanes.html>

LONG-TERM GOALS

Our primary goal is to contribute to our understanding of air-sea surface flux processes in high winds, specifically in the complex conditions of tropical hurricanes through the development and application of microwave remote sensors.

OBJECTIVES

Our scientific objective is to collaborate with and support Dr. Peter Black and Co-investigators to meet the goals set forth in the proposal entitled, Air-Sea Flux Estimation in High Wind Boundary Layers (ONR Award #N00014-01-F-009). In particular, we will

- 1) provide continuous surface wind vector and wind stress measurements as well as atmospheric boundary layer (ABL) vertical wind profiling in large wind speed gradient regimes such as storms and hurricanes through the use of microwave remote sensing instruments (This is for ONR grant #N00014-01-1-0923 entitled, UMass Participation in Air-Sea Flux Estimation in High Wind Boundary Layers, hereafter referred to as CBLAST-SCAT),
- 2) provide and maintain a central web-based data archive that will allow easy secure access to the data set collected during ONR/HRD CBLAST field experiments as well as provide web pages describing the ONR/HRD CBLAST program for the general public and scientific communities (This is for ONR grant #N00014-01-1-0834 entitled, WEB Based Data Archive for the High Wind C-Blast Project, hereafter referred as CBLAST-WEB).

APPROACH

To meet our first objective, we will modify the current version of UMass' scatterometers, CSCAT and KUSCAT, to image the 3-D atmospheric boundary layer (ABL) winds by acquiring Doppler/reflectivity profiles of precipitation simultaneously at four separate incidence angles (approx. 30, 36, 42 and 50 degrees) while conically scanning. This modified version of scatterometers, referred to as IWRAP (Imaging Wind and Rain Airborne Profiler), will be flown with an improved version of the UMass Simultaneous Frequency Microwave Radiometer (USFMR) on the NOAA N42RF aircraft. Fig. 1 illustrates the measurement geometry.

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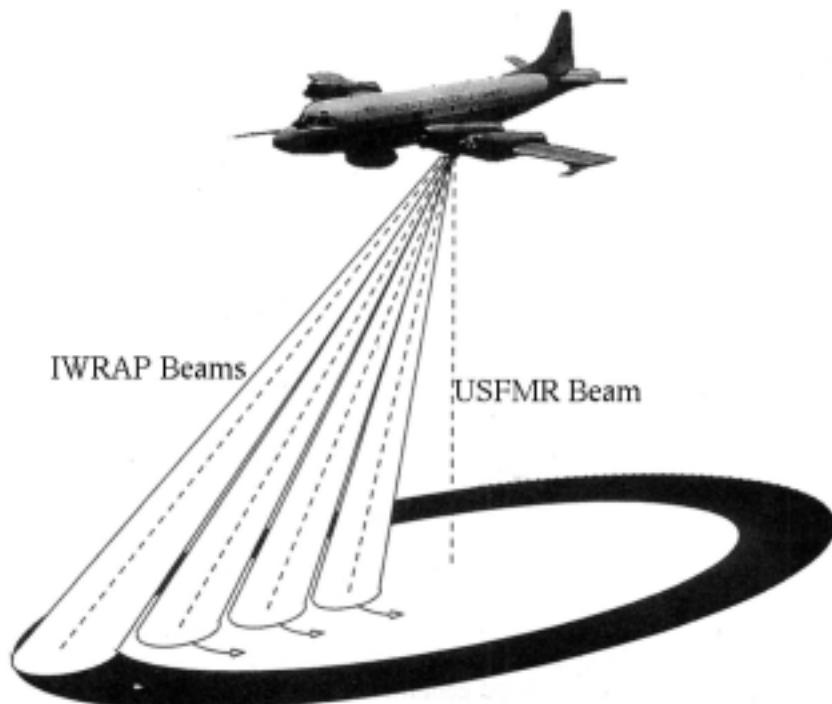


Figure 1. IWARP/USFMR observing geometry

The Doppler profiles at each incidence angle and conical scan will be mapped to a three dimensional grid with a cell size of approximately 150m x 150m x 60m. For each cell, Doppler measurements at the four incidence angles and multiple azimuth angles will be acquired, and from these measurements, the three components of the wind estimated. Surface wind field will be derived from the backscatter imagery collected with each profile. The USFMR provided surface wind speed and rain rate estimates at a one hertz rate.

To meet our second objective, UMass will work with the CBLAST team members and ONR sponsors to design and implement a web server to post a series of web pages describing the ONR CBLAST program, data and results, and provide secure access to a terabyte RAID system where the CBLAST data sets will be kept. A second terabyte RAID system will be added during FY03 to accommodate the increasing amount of data. We will leverage our experience in developing a similar data archive web site for the CPRS (Cloud Profiling Radar System) project. (Our CPRS web site can be found on the web at <http://abyss.ecs.umass.edu/cprs-web>. To access the data archive section of the web, use the following guest account - username: guest, password: cprsdata)

Professional web interface design for the CBLAST web server has been budgeted and will be carried out by web designer Tom Sweeney at the Engineering Computer Service at University of Massachusetts. A site developed by Tom Sweeney, showing an example of his work, can be found at <http://www.ecs.umass.edu/development>.

The UMass CBLAST effort will be led by Prof. David J. McLaughlin, with Alex Xuehu Zhang assisting.

WORK COMPLETED

CBLAST-SCAT (D. McLaughlin and A. Zhang)

Our CBLAST-SCAT proposal anticipated funding for FY01 starting on 10/01/2000, but the actual start date for our grant was 05/24/2001. Consequently, this report summarizes our accomplishments made over a 4-5 month period rather than an entire fiscal year for our CBLAST-SCAT proposal. The proposed FY01 activity for UMASS was to upgrade the UMass C and Ku-band airborne scatterometers into an Imaging Wind and Rain Airborne Profiler (IWRAP) to enable the instrument to image (in 3-D) atmospheric boundary layer winds and precipitation. Tasks for FY01 are:

- 1. Boost the transmit power of C and Ku-band from 1 watt to 80 watts by integrating microwave power modules (MPM) into the C and Ku-band transmitters.**

The C and Ku-band power amplifiers have been ordered from Microwave Amplifiers Inc. (C-band solid state amplifier) and Northrop Grumman (Ku-band Microwave Power Module or MPM) and are scheduled to be delivered in October (for C-band) and November (for Ku-band) 2001 time frames. These modules will then be integrated into new RF transmitter boxes that have been fabricated. In the event these amplifiers are not delivered by their promised dates, we are able to install two smaller amplifiers currently available at UMass to provide 10W (C-band) and 20W (Ku-band) transmit power, on a temporary basis for system testing during planned NOAA WP-3 2002 winter storms flights for P. Chang (NOAA/NESDIS/ORA). The impact on IWRAP's sensitivity will be a 9dB reduction in signal-to-noise ratio (SNR) at C-band and 6dB SNR reduction at Ku-band.

- 2. Incorporate a four channel digital receiver into the IWRAP C and Ku-band receivers to enable IWRAP to simultaneously record the Doppler/reflectivity profiles at four separate incidence angles (approx. 30, 36, 42 and 50 degrees incidence) and two frequencies.**

To date, we have completed approximately 70% of the work needed for digital receiver implementation. A block diagram of the digital receiver system is given in Figure 2. We expect to finish the digital receiver integration by 12/01/01 to test the IWRAP system during 2002 NOAA/NESDIS/ORA flights (01/2002-03/2002).

Key to this development is processing firmware (Field Programmable Gate Array codes) being developed by Andraka Engineering, under subcontract. Since this is a critical subsystem in the IWRAP radar development, we will carefully monitor the subcontractor development of this task during October and November and use this status to rationally plan for the timing of the 2002 winter flights of the IWRAP system.

- 3. Incorporate high power internal calibration loops to IWRAP in order to record transmit waveforms and measure transmitter/receiver gain fluctuations.**

This work has been completed.

4. Test and calibrate IWRAP at the UMass outdoor calibration range.

The test and calibration of the IWRAP system at the UMass outdoor calibration field will be carried out in early December 2001. This task will include observing corner reflectors at varying ranges and characterizing the system gain stability as a function of the instrument's internal temperature environment. This task is estimated to take two weeks.

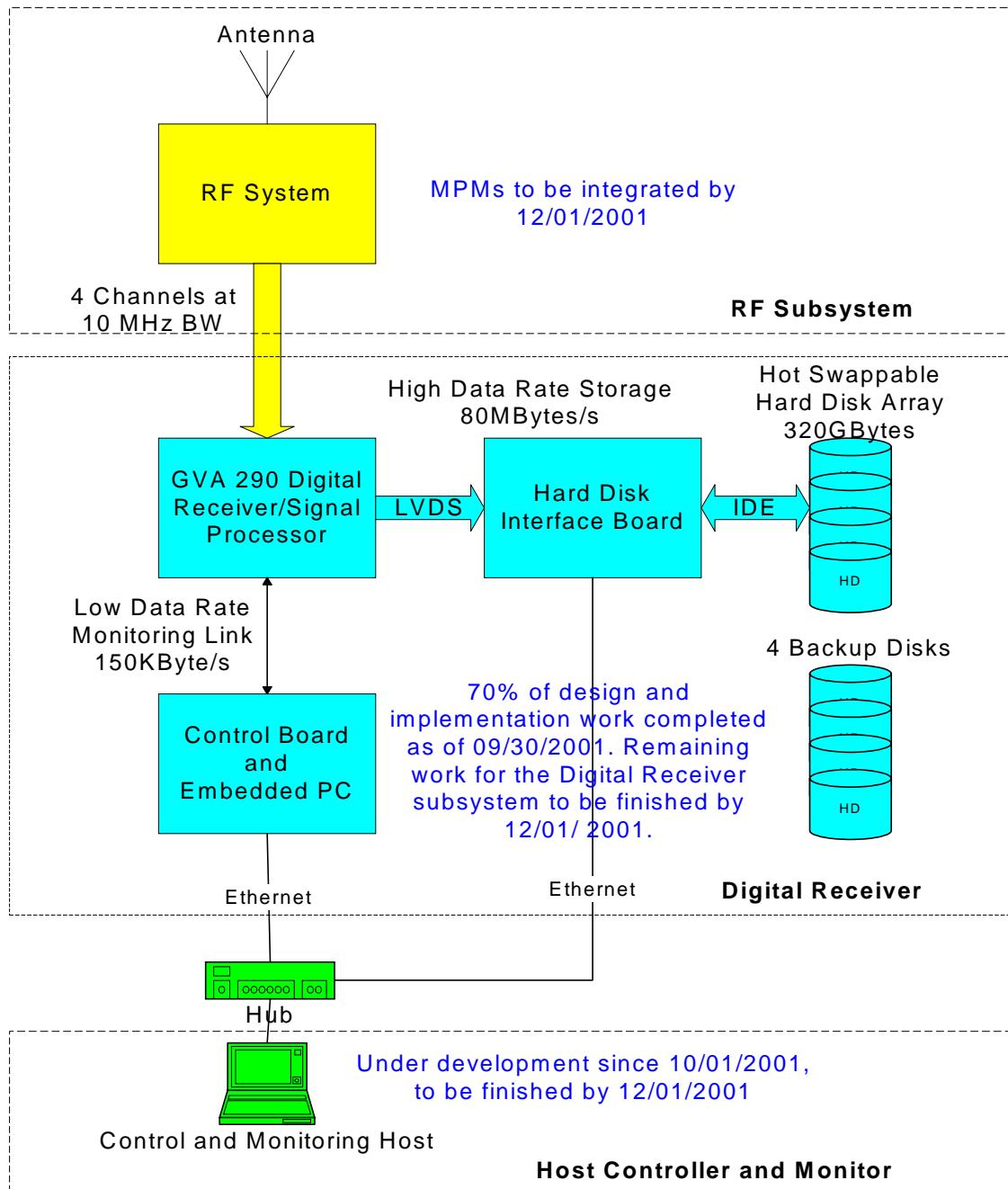


Figure 2. IWRAP System Diagram

5. Integrate IWRAP into the NOAA WP-3D aircraft.

Integration of IWRAP into NOAA WP-3D aircraft is scheduled to be carried out late December 2001.

- USFMR Work**

Though not specifically addressed in our CBLAST proposal for FY01, UMass participated in Hurricane flights aboard NOAA AOC aircraft during August – October of 2001, refined system calibration and successfully tested a real-time transmission of surface wind data to the National Hurricane Center. For future research archives, 8 flights were flown through 4 storms collecting a total of 460 Mbytes of data. These flights are listed in Table 1

Table 1. USFMR Participated Flights in NOAA 2001 Hurricane Field Program

Flight	Date	Storm/(MISSION)	Data Amount (MegaBytes)
1	09/10/01	Erin	72.8
2	09/15/01	Gabrielle	54.5
3	09/16/01	Gabrielle	36.1
4	09/19/01	(KAMP)	39.8
5	09/22/01	Humberto	78.5
6	09/23/01	Humberto	62.3
7	09/24/01	Humberto	60.9
8	10/07/01	Iris	55.8

The proposed FY02 activity is to

- 1. Develop software for processing IWRAP profile data into backscatter images and wind field maps.**

We have started this work on 10/01/2001. This software will process the measurements from the scatterometers into high resolution surface backscatter images, high resolution wind vector field maps and retrieve the 3-D wind field from Doppler measurements of precipitation. This code will serve as the basis to realize real-time processing of the high resolution 3-D and surface wind fields during CBLAST deployment in FY03 – FY04.

- 2. Participate the 2002 HFP with IWRAP and USFMR.**

We plan to install the IWRAP and USFMR systems on to the NOAA WP-3D aircraft in December 2001 to participate in the 2002 NOAA/NEDIS/ORA winter storm flight experiment. This will serve as an engineering check of IWRAP hardware and software to prepare for hurricane flights that will take place in August-October of 2001. If necessary, modifications to the IWRAP system will be made during summer 2002 to ensure successful operations during 2002 HFP flights.

- 3. Add dual polarization capability to the IWRAP system.**

The dual polarized antennas have been ordered from Ball Aerospace (\$139K, funded by Oregon State University/NASA) and are scheduled to arrive at UMass in January 2002. We are currently working on

a design to add dual polarization imaging capability to the C-band and Ku-band spinners. (The current spinning mechanisms use single RF channel rotary joints to pass radar signals between the spinning antenna and the non-rotating RF electronics in the radar). Two approaches are being considered at this point. The first is to replace the single channel RF rotary joints with dual channel joints to pass both polarizations. To date, we have been unable to locate a dual channel rotary joint that will accommodate the wide bandwidth of the IWRAP system (bandwidths needed to frequency-scan the antennas are 500MHz at C-band and 1GHz at Ku-band). We are pursuing a lead from Q-par Angus Ltd. The second design option is to install a polarization switch on the spinning dual-polarized antenna and use a single channel rotary joint with slip rings. The power and control signals of the polarization switch will be passed through the slip rings.

We plan to finish the dual-polarization upgrade for the spinners during the spring of 2002 then install the dual polarized antennas into the radar prior to hurricane flights.

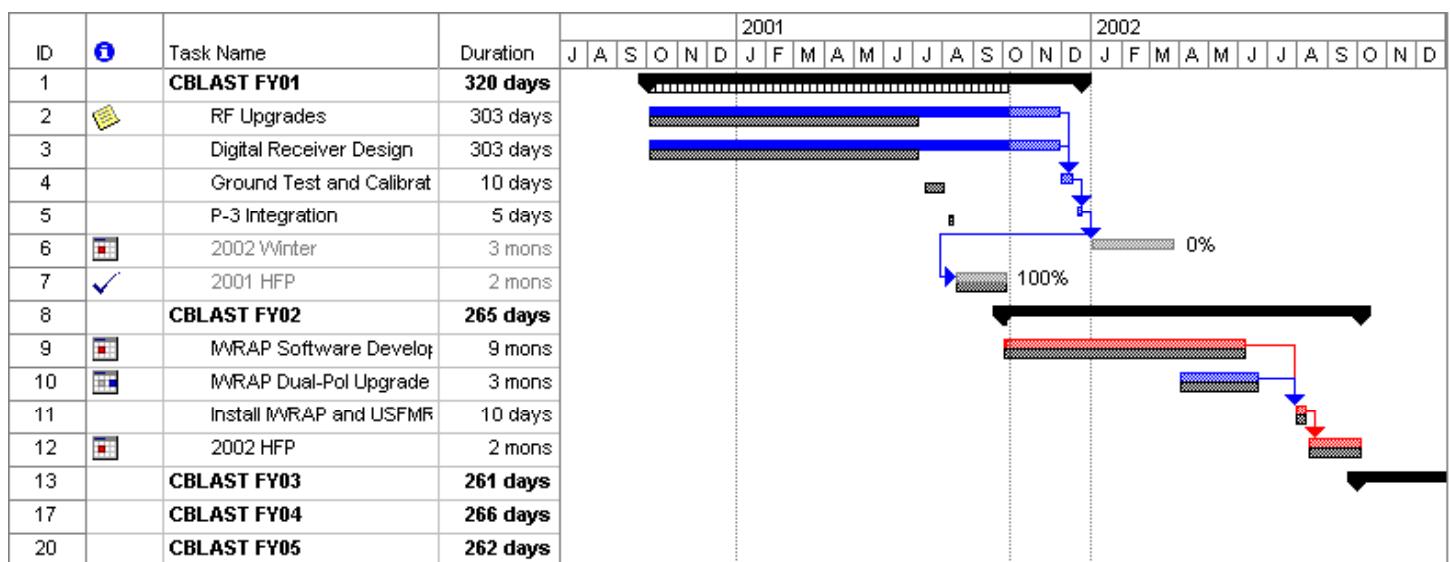


Figure 3. UMass CBLAST Project Schedule

*Gray bars denote the original proposed schedule.
Blue and red bars denote current plan (shaded color) and progress (solid color).
Black bars denote summary tasks.*

NOTES:

- 2001 HFP involved the UMass SFMR only and resulted in the data set summarized in Table 1.
- 2002 winter flights will involve both the SFMR and the IWRAP. A detailed plan for flight hours to test IWRAP and collect precipitation measurements will be made in conjunction with Dr. Paul Chang, representatives of NOAA HRD, and CBLAST collaborators.
- 2002 HFP will involve both the UMass SFMR and IWRAP instruments.

CBLAST-WEB (A. Zhang)

UMASS has received the first Terabyte RAID system from MegaHaus and been setup at UMass/MIRSL computing lab. The second one will be added in 2003. The web server machine has arrived and is being configured with the server software and web site deployment tools. A meeting or conference call will be held to collect user requirements and finalize data formats and other specifications from our various CBLAST partners. We plan to finish the web site development prior to the 2002 winter storm flights. The data collected during these flights will be archived and served from the UMass CBLAST web site. We plan to connect the CBLAST web server to the Internet2 backbone at University of Massachusetts.

RESULTS

McLaughlin and Zhang, replacing Carswell who accepted a new position in private industry, have tested a new and improved version of the SFMR for surface wind and rain estimation- called the USFMR- during the 2001 hurricane season, showing successful performance except for a minor problem with USFMR radome integrity, a problem that prevented routine real-time wind estimation for NHC, and that will be corrected during FY02. They have also purchased hardware and nearly completed fabrication of a new design for their dual-frequency scatterometer system, CSCAT and KSCAT, to convert it into a dual-frequency, dual-polarization Doppler wind profiling system called Imaging Wind and Rain Airborne Profiler (IWRAP). This will enable the instrument to image (in 3-D) atmospheric boundary layer winds and precipitation, and produce continuous PBL wind profiles along the aircraft flight track.

Zhang has purchased the hardware for a web-based data archive and begun development of the software. The first terabyte RAID system has been set up and a second is on order. This effort will provide and maintain a central web-based data archive and will allow secure access to the data collected by CBLAST investigators during the 5 year span of this program. Completion of the web site and initial testing with aircraft data sets from FY02 winter storms flights is expected by January, 2002.

IMPACT/APPLICATIONS

The impact of the nearly-completed IWRAP system by **McLaughlin and Zhang** will be significant in its ability to provide continuous wind and rain profiles along the flight track extending to the surface. It will enable the flux measurements and GPS sonde observations of wind and thermodynamics at discrete points along the flight track to be placed in the context of strong gradients, especially in the eyewall. The system will provide truly vertical profiles rather than slant-wise profiles provided by the GPS sondes as they are advected by the strong winds. In concert with the USFMR, this system will allow complete mapping of hurricane surface winds for co-location with surface wave spectra measured by the laser altimeter and the SRA operated by other CBLAST scientists on board the research aircraft. These instruments will also provide the bulk variables for comparison with in-situ turbulence measurements as well as the sea spray measurements.

The impact of the web-based data archive by **Zhang** will be to provide a central site for easy archive and retrieval of CBLAST data sets by all CBLAST PIs in near real time. It will also provide for a central Hurricane CBLAST web site for PIs to use in describing initial results of their studies.

TRANSITIONS

This work is serving to prepare for initial instrument testing and installation in the second hurricane CBLAST year next summer.

RELATED PROJECTS

Air-Sea Flux Estimation in High Wind Boundary Layers, ONR Award #N00014-01-F-009.

SUMMARY

Hardware has been purchased and fabrication is ongoing for the IWRAP continuous wind profiling system. USFMR has been successfully tested during the 2001 hurricane flights. Problem found with the radome integrity will be fixed during 2002 experiments. Computer equipment for the web-based archival system has been received and software development has begun. Testing of IWRAP and the web based archival system is planned for the 2002 winter storms flight program.